Mathematical Epidemiology Tutorial 2003

Sponsored by

Los Alamos National Laboratory
Center of Nonlinear Studies
Motorola Building, Room 203-A

July 2 – July 3

Organizers:

Sara Del Valle
Ariel Cintron
Miriam Nuno
Fabio Sanchez
Gerardo Chowell
Rod Garcia

Speakers:

Horst Thieme	*Arizona State University*
Fred Brauer	*University of British Columbia*
Zhilan Feng	*Purdue University*
Herbert Hethcote	*University of Iowa*
Christopher Kribs	*Univ. of Texas at Arlington*
Abdul- Aziz Yakubu	*Howard University*
Baojun Song	*Cornell University*
Norman Johnson	*LANL*
Stephen Wirkus	*California State Polytechnic University*

Wednesday July 2, 2003

8:30 – 9:00 *Coffee and Refreshments*

9:00 – 10:00 *Horst Thieme*

"The most basic stage-structure population model with density-dependent transition rate".

10:00 – 11:00 *Zhilan Feng*

"Optimal Control of Treatments in a Two-strain Tuberculosis Model".

11:00 – 11:15 *Coffee Break*

11:15 – 12:15 *Abdul-Aziz Yakubu*

"Discrete-Time Epidemic Models".

12:15 – 1:15 *Lunch*

1:15 – 2:15 *Christopher Kribs*

"Modeling Vaccination Programs".

2:15 – 3:15 *Horst Thieme*

"Building on the Most Basic Stage-Structured Population Model:

(1) Apparent Allee effects in predators feeding on stage-structure prey.

(2) Cannibalism in tiger salamanders.

3:15 –3:30 *Coffee Break*

3:30 – 4:30 *Norman Johnson*

"Issues in the Prediction of the Future State of an Ongoing Epidemic".

Thursday July 3, 2003

8:30 – 9:00 *Coffee and Refreshments*

9:00 – 10:00 *Herbert Hethcote*

"Thresholds in Epidemic and Endemic Models of Infectious Diseases".

10:00 – 11:00 *Christopher Kribs*

" Disease Models with Switches".

11:00 – 11:15 *Coffee Break*

11:15 – 12:15 *Stephen Wirkus*

"Numerical Solutions of Delay Differential Equations".

12:15 – 1:15 *Lunch*

1:15 – 2:15 *Baojun Song*

"Forward or Backward at R_0=1".

2:15 – 3:15 *Herbert Hethcote*

"Effects of Delays in Epidemiology Models".

3:15 –3:30 *Coffee Break*

3:30 – 4:30 *Fred Brauer*

"Periodic Environments and Periodic Harvesting".

Program Abstracts and Titles

Speaker: Horst Thieme

Talk Title (1):

"The Most Basic Stage-Structure Population Model with Density-Dependent Transition Rate".

Abstract:

A population model is considered which discriminates between juvenile and adult individuals and is formed by a planar system of ordinary differential equations. The per capita transition rate from the juvenile to the adult stage is assumed to depend on the respective densities. If this transition rate is only mildly affected by the juvenile density, the population either goes extinct or converges to a unique equilibrium. If there is a strong dependence on the juvenile density, the population dynamics can become as complex as they can get in the plane. This includes bistability between several equilibria or between equilibria and periodic orbits and both super- and sub-critical Hopf bifurcations. This elementary model gives an idea of the complexity of dynamics one may expect for more realistic physiologically structured population models.

Talk Title (2):

Building on the Most Basic Stage-Structured Population Model:
(1) Apparent Allee effects in predators feeding on stage-structured prey (joint work with Andre de Roos and Lennart Persson).

(2) Cannibalism in tiger salamanders.

Abstract:

(1) The most basic stage-structured population model with density dependent transition rate is used as a building block in studying the effects of stage structure in prey on the predator. If a predator only feeds on the juveniles or if it feeds on the adults and the juvenile maturation rate weakly depends on juvenile density, there is at most one prey-predator equilibrium. However, if the predator only feeds on adults and the juvenile

maturation rate strongly depends on the juvenile density, multiple prey-predator equilibria can occur. This phenomenon appears like an allee effect for the predator.

(2) The basic stage-structured model is extended for tiger salamander populations to incorporate juvenile stages of typical and cannibalistic larvae. It is shown that a cannibalistic salamander strain can invade a typical salamander strain if the probability of surviving the cannibalistic larval stage is greater than the probability of surviving the typical larval stage.

Speaker: Zhilan Feng

Talk Title:

"Optimal Control of Treatments in a Two-strain Tuberculosis Model".

Abstract:

Optimal control theory is applied to a system of ordinary differential equations modeling a two-strain tuberculosis model. We consider (time dependent) optimal control strategies associated with case holding and case finding based on a two-strain TB model. The case finding effort is incorporated by adding a control term that identifies and cures a fraction of latent individuals so that the rate at which latent individuals develop the disease will be reduced. The case holding effort is incorporated by adding a control term that may lower the treatment failure rate of individuals with active sensitive TB so that the incidence of acquired drug-resistant TB will be reduced. Our objective functional balances the effect of minimizing the cases of latent and infectious drug-resistant TB and minimizing the cost of implementing the control treatments.

Speaker: Abdul-Aziz Yakubu

Talk Title:

"Discrete-Time Epidemic Models".

Abstract:

Discrete-time S-I-S epidemic models are presented. Thresholds for disease persistence are computed and used in the study of the global behavior of solutions of simple epidemic processes. The potential dynamic complexity of the epidemic process on chaotic

attractors is illustrated. Finally, the potential role of delayed recruitment (age-structure) on disease is explored via a simple model that differentiates between adults and juveniles. A method for constructing epidemics on Hopf invariant closed curves or chaotic attractors is outlined.

Speaker: Christopher Kribs

Talk Title (1):

"Modeling Vaccination Programs".

Abstract:

This talk will discuss modeling issues that arise in modeling the effects of vaccination programs and other control measures, including various properties of these programs and the effects of modeling decisions on the form of R_0 and other analysis.

Talk Title (2):

"Disease Models with Switches".

Abstract:

Changes in subpopulations during the course of an outbreak can cause shifts in the constraints governing a system: for example, a disease which induces some fatalities or removals from the population could, in a sufficiently severe outbreak, reduce the population faster than recruitment can replace them. In such situations, two models may be necessary to account for both cases, with a switch connecting them to allow a smooth transition between the two as conditions change over time. This talk will present two examples of such switching models and observe the types of behaviors exhibited by these hybrid models.

Speaker: Norman Johnson

Talk Title:

"Issues in the Prediction of the Future State of an Ongoing Epidemic".

Abstract:

An actual epidemic represents a single realization out of many possible realizations. For example, if one could "play the tape" again, an actual epidemic may have quite different outcomes. This presents severe challenges to those wanting to predict the future state of an ongoing epidemic. Agent-based simulations, almost by definition, exhibit the same challenges and offer an ideal medium to address these issues and develop the needed methodologies. Unfortunately, the application of most agent-based simulations is by repeating simulations to obtain a stochastic characterization of the system behavior or by carefully tuning the initial and operating parameters to duplicate a desired outcome. These uses of agent models are largely descriptive, attempting to provide understanding of the connection of agent behavior and interactions to global behavior (the self-organization or emergence problem). These uses do not address the alternative need: to predict future states from knowledge of past states. This application is comparable to the use of weather simulations tools to predict tomorrow's weather based on historical data. Similarly, we must begin to prepare for the rich data sources being developed that are compatible with agent simulations of epidemics. Unfortunately, the data assimilation methods developed for weather simulations are not applicable to agent-based simulations. This talk discusses the issues that one must consider in using agent-based models for prediction. The analysis illustrates how classical methods of predicting future states of distributed systems, e.g., statistical mechanics, are violated by the network nature of agent model, in which the probability distribution functions are highly localized rather than being applicable to the entire system. This local isolation of the evolution of the "phase space" or operational space is found to duplicate new understandings in the fields concerned with anomalous distributions and non-extensive thermodynamics.

Speaker: Herbert Hethcote

Talk Title (1):

"Thresholds in Epidemic and Endemic Models of Infectious Diseases".

Abstract:

In epidemiology models, thresholds often determine if an epidemic occurs or if a disease remains endemic (i.e. it persists in the population). Typical thresholds are the initial replacement number, the contact number, and the basic reproduction number. The ideas are illustrated in simple models and then methods of determining thresholds in models with social groups and age groups are presented.

Talk Title (2):

"Effects of Delays in Epidemiology Models".

Abstract:

In compartmental models of infectious disease, time delays can be used to model the residence times in a compartment. Thus they could correspond to latent periods, infectious periods, or periods of temporary immunity. Models with time delays are formulated as integral equations or delay-differential equations. These models may have a richer dynamical behavior than the corresponding ordinary differential equations models corresponding to exponentially-distributed residence times. in some cases periodic solutions arise by Hopf bifurcation. Examples of SIS, SIRS, SEIRS types will be presented.

Speaker: Stephen Wirkus

Talk Title:

"Numerical Solutions of Delay Differential Equations".

Abstract:

An important component of continuous-time models involves numerically solving the differential equations. Many standard software packages are available but students often simply accept the innerworkings of the given program. This tutorial will begin with a review of the standard 4th-order Runge-Kutta method for non-delayed equations. Examples of models where a delay naturally arises will then be given and the Runge-Kutta method will be seen to be modified in a natural way to account for this delay.

Speaker: Baojun Song

Talk Title: "Forward or Backward at R_0=1".

Speaker: Fred Brauer

Talk Title:

"Periodic Environments and periodic harvesting".